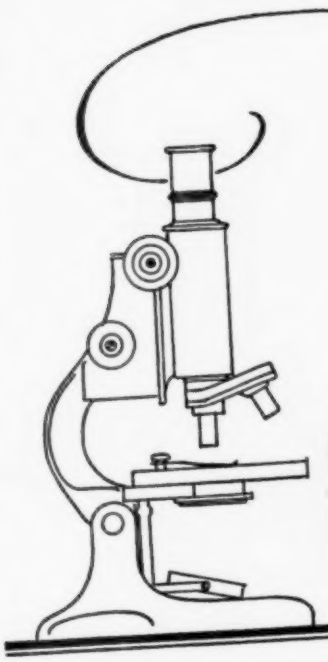

The SCIENCE COUNSELOR

A Quarterly Journal for Teachers of Science in the Catholic High Schools

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NUMBER 1
MARCH, 1938

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The Science Counselor

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Science Essay Contest . . .

Winners in the national science essay contest held in connection with Duquesne University's sixth annual Conference for teachers of science were made known on February 19. To the winner of the highest honor has been sent a gold medal for permanent possession; to the winner's school, for one year's possession, a silver cup suitably engraved. Five honorable mentions, all of equal value, were announced by the committee of judges which was composed of members of the Education, Arts, Science, and Pharmacy faculties of Duquesne University.

The subject selected for the 1938 essay contest was "Science in the Laundry." Several hundred students participated. The winning essay will be published in the June number of the SCIENCE COUNSELOR.

The winner of the gold medal:

Miss Florence A. Obert,
The Bishop McDonnell Memorial High School,
Brooklyn, N. Y.

Her work was supervised by Sister M. Thomas Aquin, O.P.

Honorable mentions:

Clemence Lachowsky, St. Joseph High School, Conway, Arkansas. Supervised by Sister Mary De Deo, S.S.N.D.

Leonard T. Willey, St. Joseph Academy, St. Augustine, Florida. Supervised by Sister M. Ambrose, O.S.J.

Kathryn Kennedy, Madonna High School, Aurora, Illinois. Supervised by Sister M. Aida, O.S.F.

William W. Hartney, Leo High School, Chicago, Illinois. Supervised by Brother W. A. Hennessy, F.S.C.H

Thomas F. Gallagher, Immaculate Conception High School, Lock Haven, Pa. Supervised by Sister Anna Maria of the Sister Servants of the Immaculate Heart.

The Snowflake

• By Sister Mary Gertrude Quinn, O.P., M.A., *(Columbia University)*
INSTRUCTOR IN SCIENCE, TRINITY HIGH SCHOOL, RIVER FOREST, ILLINOIS

From a Bentley Original

God loved a lonely raindrop
And drew it to the skies
He tenderly caressed it
And wiped its tear-dimmed eyes.

He decked with airy lightness
Its little form so trim
And gave it for its play land
A fluffy cloudlet's brim.

To magic crystal whiteness
It changed at His command
Reflecting God's perfection
It fell from out His hand.

Science Teaching in Puerto Rico

● By Dr. José M. Gallardo and Mr. Jacinto Sugrañes
COMMISSIONER OF EDUCATION SUPERVISOR OF SCIENCE
DEPARTMENT OF EDUCATION, GOVERNMENT OF PUERTO RICO, SAN JUAN

Science teaching in Puerto Rico follows modern lines.

It may surprise some of us (who know far too little about our neighbors) to learn of the use in Puerto Rican schools of motion pictures, radio broadcasts and other modern aids in science instruction. How well the whole science plan has been thought out, and is being executed, is told in this article.

It throws interesting light on education in Puerto Rico.

●

This article could well be entitled "Teaching Science in Nature's Paradise," for in Puerto Rico nature is so exuberant that with little effort one can find specimens of plant or animal life suitable for the explanation of any fundamental process or principle of nature. Located 18° North of the equator, the island has in its flora and fauna numerous specimens of the tropical and temperate regions, and at night there is a magnificent display of stars and constellations. In the winter months, when the sky is clearest in Puerto Rico, the great Nebulae of Orion and Andromeda can be seen with the naked eye.

Puerto Rico is a mountainous country 100 miles long by 35 miles wide, bounded by the Caribbean Sea on the south and the Atlantic Ocean on the north. The mean annual temperature ranges from 73° F. in winter to 79° F. in summer, while in the mountains temperatures as low as 54° F. have been recorded. The continuous trade winds that blow over the island, the mild climate, the vegetation and fauna, the absence of poisonous reptiles and wild animals, and the splendor of the heavens make this spot one of nature's laboratories and a paradise for the teacher of science.

Conscious of this abundance of natural phenomena and of the need of acquiring a complete knowledge and understanding of them, the Department of Education has always been vitally interested in the teaching of both elementary and high school science. In the high schools science instruction has changed little during the past three decades, except for the frequent adoption of new revised texts. The system followed is the orthodox one: General Science during the first year, and specialized courses in Biology, Physics and Chemistry during the second, third and fourth years. All high schools have good laboratories equipped with the proper paraphernalia including gas and electricity. The objectives of science instruction in the high school have been the development of an understanding of natural phenomena, the acquisition of the scientific method of thinking and the preparation of students for colleges and universities.

The teaching of science in the elementary school, however, has undergone radical changes since 1900. In the past two years complete courses have been prepared for the first four grades, and tentative courses for the fifth, sixth, seventh, and eighth grades. A bulletin on the methodology of science teaching to precede all courses of study has been issued. The purpose of this bulletin is to orient teachers in the modern method of science instruction. Its content includes the general objectives of elementary science instruction in Puerto Rico, the principles of selection and organization of subject matter, the different methods of instruction with special emphasis on field trips, problem solving, demonstration and laboratory experimentation; instructions for testing and measuring instructional results; and instructions for the organization and best use of laboratory rooms and equipment. An extensive bibliography completes the bulletin.

The guiding principle in the preparation of the course of study has been the belief in the gradual and concomitant development of the mental abilities of the child. Each year the material is considered under six heads: The Earth, Beyond the Earth, Conditions Necessary to Life, Living Things, Physical and Chemical Forces and Phenomena, and Man's Control of his Environment. The courses for the various years differ only in intensity and specialization, thus forming a continuous, correlated program. The subject matter is selected mainly from the environment of the child and organized in accordance with Professor Morrison's Unit System. The life situations and daily experiences of the children are fully considered. In passing, it may be of interest to note that the children exhibit more or less the same physical and psychological characteristics as the children of any other civilized country.

At present the instruction in elementary science is conducted in Spanish and English, the time allotted to instruction in each language depending on the grade. Modern media of instruction are used. The urban schools and the vocational rural schools are serviced with alternating current, which makes possible the use of visual equipment and radio. The Department of Education has a number of movie projectors and several dozen scientific reels which are rotated in the schools of the island. The Department has at headquarters a complete radio studio from which science programs are broadcast.

At present a revision of all courses of study is under way. The first grade period will be used as an ex-

Continued on Page Twenty-five

An Integrated Senior Course in Science For the Non-College Pupil

• By George L. Bush
ASSISTANT PRINCIPAL, SOUTH HIGH SCHOOL, CLEVELAND

A new venture in high school science teaching! Instruction in science designed to meet the needs of the non-college pupil at last.

Here is described a special general course in senior science suited to the needs of many pupils who would ordinarily finish school with no science instruction beyond the ninth or tenth year. So attractive is the new plan to pupils, parents, and teachers that it is receiving wide consideration.

The writer of this article is an enthusiastic pioneer in the field. The interesting new textbook, "Senior Science," designed to fit this course and written by Bush, Ptacek, and Kovats, was reviewed in our issue of June, 1937.

Most high school pupils do not attend college.

Nearly everyone engaged in the work of education is informed about the changing population of our high schools, changing because of the addition of large numbers of pupils from that part of our population which was never before represented in so-called higher education. Even in the last ten years our high school enrollment has kept pace with the increasing population, and then has nearly doubled.

In our cosmopolitan high schools these pupils have formed crowded classes in wood work, metal work, automobile repairing, foods, clothing, typing, shorthand, and similar subjects. In many of our cities special schools are being operated along technical, commercial and home management lines. These pupils and their parents have not been satisfied with the formal physics and chemistry common in our high schools. Thoughtful science teachers and school administrators have known for some time that these traditional science courses were not adequately meeting the needs of the big majority of the pupils. The steady drop in the percentage of elective enrollments in physics and chemistry has been further evidence along this line. However, in fairness to physics and chemistry we should remember that this drop is not in numbers but in percentage, and is due to the influx into high schools of pupils who do not fit into the traditional physics and chemistry courses.

Usually, when one begins to comment upon the educational needs of our non-college and low ability pupils, a counter argument arises as someone inserts the objection that we must give our attention to the education of our leaders. With that there can be no dispute. Certainly our future leaders deserve every attention that we can give them, but the democratic nature of our country also demands well informed followers. Therefore, it appears entirely evident that it is not only not economical but not possible to continue to give a leader type of science education to the thousands of future common citizens in our high schools.

If we attempt to determine the needs of high school pupils by a brief study of the occupations in our world today, we find that these occupations may be put into three very general classes. There are the occupations which are classed as professions. Among these are the doctors, dentists, nurses, clergymen, teachers, writers, engineers, and research specialists. In general these are the occupations which require extensive education beyond the high school, for which advanced education the high school furnishes the preparation. As is well known, it is for some of the professions that the formal and somewhat abstract physics and chemistry have their chief value. Only about twenty per cent of our people are engaged in the professions.

A second group of occupations is generally called the trades. Here are the machinists, plumbers, carpenters, painters, brick-layers, automobile, airplane, and steamship mechanics, printers, farmers, and stenographers. For suitable success these occupations require specialized training along definite lines. Some of this training can be and is given in the high school. Some of it must come in special courses beyond the high school or parallel with it. For the trades the traditional physics and chemistry are occasionally desirable but they are must less important than they are for the professions. About twenty-five per cent of our people are engaged in the trades.

The remainder of our working people—more than fifty per cent—are occupied at what we commonly call jobs. In this group are the railroaders, truckers, bus drivers, general factory workers, operators of automatic machinery, grocery clerks, sales girls, janitors, and home workers. Into work of this sort go more than half of our high school pupils.

Altogether these non-college pupils, who make up about three-quarters of our high school population and who are to become our common citizens, will spend nearly all of their time and money in the purchase of foods, medicines, and clothing, in the construction and equipment of modest homes, in the use of modern appliances for home activities and recreation, and in the enjoyment of the family automobile. It seems highly essential that these common citizens should leave our high schools with an intimate knowledge and appreciation of these things and of the part that science has

had and will continue to have in the lives of all of us. In Cleveland, about fourteen per cent of the high school graduates now go to college and a similar condition probably prevails in other industrial cities. For the entire country, various estimates indicate a range of twenty to thirty per cent, although in this connection it is well to remember that these figures do not consider at all the appallingly large numbers of pupils who withdraw from high school during the eleventh and twelfth years. Certainly, science owes to these many pupils who withdraw before their graduation, and to the seventy or eighty per cent of non-college pupils among those who do graduate, something other than college preparatory science.

•

Senior science gives and applies practical information.

In Cleveland, we believe that we have developed a satisfactory science course for these non-college pupils. The course has been in a process of development for about nine years, and has during the past year, through the publication of a textbook, had a somewhat amazing spread over the entire country. On the whole, the course is open to eleventh and twelfth year pupils who will end their formal education before or at the time of their graduation from high school. We have called the course "Senior Science" in order to differentiate it from physics and chemistry and from the usual ninth year general science course. It is believed that this senior science course accomplishes two things. It furnishes a practical useful science course for the non-college pupil, and it permits a higher grade of work to be done in the college preparatory classes. The general aim of the course is to give and apply practical information with some of the applications being carried to completion only after the pupil takes his place as an adult citizen in the community. This kind of a science course appears to be a necessity in order to keep step with the most pronounced tendency in modern education—namely, the fitting of the school to the practical needs of the pupil.

The senior science course as developed, differs from the usual physics and chemistry in three general ways: (1) It cuts completely across the common subject matter lines, stressing practical applications rather than the more or less abstract science principles. (2) It aims strongly towards giving scientific consumer education. (3) It directs special attention to the social implications of the subject matter. In describing these three general differences, it seems advisable to give several common illustrative examples in order that the reader may form judgment from actual details of the course rather than from general theories.

With respect to the emphasis on applications, the subject material has been made as useful and practical as possible with little worry over the omission of certain scientific principles which are normally considered indispensable in physics or chemistry or even in ninth year general science. Invariably the applications come first, not only in importance but in methods of introduction and presentation as well. If the study of the nature and utility of the electric vacuum sweeper, the electric washing machine, the electric ironer, the electric refrigerator, and the electric mixer leads to an understanding of the electric motor, it is considered a desirable but not at all necessary feature of the course. The principle of the electric motor must come last if at all and must be simply expressed.

In the study of the airplane the course emphasizes the use of the airplane in searching for icebergs and wrecked ships, in locating schools of fish for fishing fleets, in the fire patrols of great forests, in sowing rice in water and mud, in fighting insects by spraying poisons, in explorations and exploratory photography, in mail service, and in the increasing general passenger service. Further detailed study concerns the size and speed of passenger planes, the provisions for safety and comfort, the use of the radio telephone, the nature and value of scientific weather reports, the nature and use of the most important among the thirty or more instruments and controls available to the pilot, the careful mechanical inspection, the Department of Commerce continuous dot-dash dash-dot radio beacon which virtually fences in the airplane route when visibility is poor, and the use of air inflation of rubber sleeves on the wings in order to break away ice. Compare the general usefulness, practicality, and interest in this kind of science information with a discussion which emphasizes thrusts, drags and lifts, combination and resolution of forces, parallelograms and resultants, and there is apparent one of the chief differences between the senior science course and physics.

With respect to giving scientific consumer education, it is seldom feasible or desirable or scientific to compare actual brands or makes of important trade products, because the worth of certain brands and makes of products changes so rapidly that the schools cannot continuously give correct information. However, it is quite feasible and desirable to study scientific methods of judging various products and to show how many of the claims made by advertisers and salesmen are certain to be incorrect. Some representative things of a consumer information nature follow:

Mineral water does not perform health miracles.

One's beauty is seldom improved by using a particular kind of soap.

Disagreeable body odors are removed by frequent bathing with any good soap.

Certain breakfast food advertising makes roughage unnecessarily important.

Strict flesh reducing diets should be followed only under the careful direction and observation of a physician.

Published testimonials for medicinal preparations are not dependable.

Thread count and length of fiber are highly important considerations in purchasing textiles.

The open-top gas range has certain advantages over the closed-top range.

The electrical dishwasher is economical only for families of more than six or eight members.

When clothes are washed longer than the proper time limit they will actually pick up a part of the dirt again and become less bright.

Plated silver marked grade "A" is actually sixth in value among the ratings generally used for silver.

These few statements illustrate the attempts to introduce at every opportunity consumer information of

a practical nature. Through newspapers, magazines, radios, and even house to house campaigns, advertisers in constantly increasing numbers have gone into the homes and touched the lives and habits of the people. It seems entirely evident that educators must learn to be more proficient along these same lines.

Although it is apparent that this consumer education has considerable social value in itself, the senior science course attempts to direct special attention to other social implications of the subject matter. As further illustrations of this social value of science the course considers: The part played by any community in developing a safe and adequate water supply; the effects of weather upon the design of homes; the function of scientific education in insuring the sale of pure foods and safe and effective drugs; community building restrictions; things to think about in buying or building a home; scientific developments with a part in home recreation; factors involved in the selection of a motor car with special attention to second-hand cars; the entire subject of safety.

•

Some duplications of ninth year science are desirable.

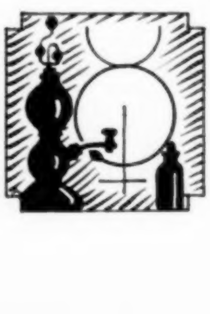
The senior science course differs from the general science courses of the junior high school in the fact that emphasis is placed upon things which have greater appeal to the interests of young people approaching maturity—young people who will complete their formal education with graduation from high school and who will frequently be making homes of their own a short time later. It is granted that there are occasional duplications between the senior course and the usual ninth year course in general science. These few duplications are necessary for proper continuity and the instructor in each of the few cases aims to make sure that the treatment is not necessarily more difficult but rather more extensive and less formal than the junior high school science. One who is inclined to think unfavorably of these few duplications should remember that similar duplications occur between physics and chemistry and junior science. For example, such subjects as the metric system; Archimedes' principle; levers, pulleys, and other simple machines; calories, magnetism; batteries; motors; steam engines; telegraph and telephone systems are common both to physics and to junior science. Similarly, such subjects as water purification, oxidation and burning, fuels, foods and vitamins, and production of various metals are common both to chemistry and junior science. Further justification for this slight repetition is apparent when it is remembered that in view of the important position of science in modern life, there is reason for the repetition in science just as there is reason for the repetition of English in each year, for the repetition of American history in eleventh or twelfth year, or for the teaching of arithmetic in the senior high school after it has been emphasized for several years in earlier grades.

Physics and chemistry have great values.

In making comparisons between senior science and physics and chemistry it is most emphatically not the purpose of this article to belittle those desirable and highly worth while subjects. Behind the abstract science principles which physics and chemistry explain and emphasize lie the scientific advances of the future—advances in which the pupils who study only senior science can have no part. Senior science was not designed to replace physics and chemistry but rather to complement those subjects and thereby give valuable instruction materials and inspiration in science to the many pupils who would otherwise graduate from high school with no science beyond the ninth or tenth year.

In Cleveland where, as previously indicated, the senior science course has been in a process of developing for some years, it has drawn from physics and chemistry very few pupils, a number of them being pupils who had not been successful in these subjects. By far the greater number of pupils who have taken the senior course in Cleveland would not have taken either physics or chemistry. Some fairly accurate investigation of this fact indicates that only about twelve out of each one hundred pupils in senior science would have taken physics or chemistry had there been no senior science. This indicates that the senior science course increases considerably the pupil enrollment in upper grade science. In the two Cleveland schools where the senior science course has been longest in operation, and where the physics and chemistry have been entirely elective subjects, the eleventh and twelfth year enrollment in science is approximately twice as great as it would have been without senior science. It is apparent, therefore, that senior science is fulfilling its purpose of making a valuable form of upper grade science available to more pupils, and that it was not designed to replace physics or chemistry.

Science organizations and science teachers have frequently recommended science for each pupil in each year of the high school. As the maximum goal attainable, it is more necessary and eminently more worth while to have science courses which attract pupils and please parents because of their usefulness, interest, and general merit, science courses which are elected by nearly all pupils because of recognized value, rather than to have the pressure of requirements which force pupils into subjects. With practical courses for the common citizen in addition to abstract courses for the professions, science can prove its worth for every one.



Vegetative Propagation

● By Sister Mary Ellen O'Hanlon, O.P., Ph.D., (University of Chicago)
CHAIRMAN, DEPARTMENT OF BIOLOGY, ROSARY COLLEGE, RIVER FOREST, ILL.

This article contains excellent teaching hints for the teacher of biology.

Here is an interesting discussion of the more common and less complex types of vegetative reproduction that are within the ability of the high school pupil to observe and comprehend.

Sister Mary Ellen is co-author of the new Hauber-O'Hanlon textbook in biology for colleges recently published by F. S. Crofts & Co., New York. This excellent biology, in which according to the authors "the name of God is not taboo," is deservedly attracting much favorable attention. It has received flattering reviews in many journals. The Editor believes that it should be in the library of every school, especially every Catholic school. Both teachers and students will find it invaluable for study and reference.

The drawings which accompany this article were made by Miss Verna Schultz.

●

In order to reproduce their kind, some of our most common seed plants must develop young plant embryos within their ovules. These ovules later ripen into seeds, each one of which contains at least one more or less well developed plantlet. The seeds are the progeny of the adult plant and constitute the succeeding generation. Because the ovules in all seed plants excepting the Gymnosperms, are situated within the ovary which later ordinarily ripens into a fruit simultaneously with the development of the seeds from the ovules, the whole process is called fructification or fruiting.

The term "fruiting," however, is often applied to other special methods of plant reproduction wherever the elements of sex are involved as in the case of many fungi, algae, mosses, liverworts, ferns and their allies. Thus, we speak of fruiting structures and fruiting processes in many plants in all of the different groups where there are neither ovules nor ovaries, the organs which are, respectively, the forerunners of seeds and fruits in the more restricted sense of the latter term. That is, the term "fruit" in some form or other is applied to all of the plants which bear special organs capable of differentiating certain cells which by their nature and function are reproductive, as in the case of all gametes, whether similar or dissimilar.

SPECIAL ASEXUAL REPRODUCTION

There are still other methods of reproduction in plants, which while they are not gametic or sexual, are at the same time sufficiently specialized to be excluded from the subject of this brief sketch. These are, for example, such methods as the development of special vegetative bodies illustrated by asexual spores, including zoospores, gemmae, bulbils and the like. These cells or organs are formed directly from the same generation, whether the gametophyte or sporophyte, into which they in turn develop. That is, the zoospores of Oedogonium or of some of the water molds, for example, are borne on the gametophyte generation and upon germination grow into new gametophytes, no alternation of generation[1] being involved.

The same is true with the gemmae of some of the liverworts and mosses which are borne on the gametophyte generation as very definite reproductive structures. These gemmae become detached and develop into gametophytes exactly like the plants which bore them. In such fern sporophytes as bear special bulbils on their leaves, Cystoptera bulbifera, for example, these bulbils fall to the ground and initiate new sporophytes, directly. These are some illustrations of propagative methods which involve the development of certain reproductive structures that are distinct but sexless.

APOGAMY AND APOSPORY

Neither do we wish to include here such phenomena as apogamy and apospory so well illustrated in some of our common ferns. Vegetative apogamy[2], as distinguished from true apogamy or parthenogenesis, consists in the direct origin of a sporophyte from the nutritive tissue of the gametophyte and, therefore, is not vegetative reproduction according to the limitations we have laid down at the outset; because it involves an alternation of generation at least in the superficial aspects of this plant phenomenon, even though the cytological test and, therefore, true alternation of generation is wanting. The same holds for apospory which may be observed in the Bracken fern, *Pteris aquilina.* Here the process of sporogenesis is sometimes omitted, and the leaf tissue which might ordinarily function as sporogenous tissue initiates young gametophytes directly. Again this is certainly a vegetative process, but since it is so specialized as to result in a plant generation completely unlike the one which bears it, we must exclude such a process from our present consideration of vegetative propagation.

SIMPLE VEGETATIVE REPRODUCTION

Our subject is, then, concerned more especially with the development of new plants from those already existing by the direct processes of sprouting, budding off, branching off, or by the regeneration of proliferations which later may and often do become detached and function as independent plants. These proliferations may take their origin from various organs or parts of organs of the parent plant, but in the end they produce

plants like to those from which they took origin. The exceptions to this rule hardly apply here. However, it may happen that certain parts of plants may mutate, and a mutant branch of a thorny blackberry, for example, may be thornless. If such a branch were to become detached and were allowed to take root and go on its own, there would be a case of progeny which would differ from the parent in at least one respect. Such cases are relatively rare in nature, and however important their application is in plant breeding, may be neglected here.

All such growths as issue from latent buds or any kind of secondary proliferations or rejuvenations which do not result in independent and separate individual plants, that is, progeny in the strict sense, are out of the picture also. And such artificial methods as grafting, budding, forced rooting, and the various experimental means employed by horticulturalists and orchardists are pertinent here only in so far as certain phenomena in nature have suggested these possibilities. Rather do we wish to demonstrate here only the more natural and less complex types of vegetative reproduction, the numerous illustrations of which are so manifest in nature and which are within the ability of the average high school pupil to observe and to comprehend.

VEGETATIVE REPRODUCTION IN SEED PLANTS

It must be borne in mind that there are certain of the seed plants which must complete their life cycle, that is, run the whole gamut from seed to seed if they are to persist. Many of our garden plants (annuals) are included in this class, that is, the plant dies with the close of the season, being unable to withstand the winter's cold. Also, some of our most important forest trees, for example, the oaks, the hickories, and the pines, show little propensity in nature to reproduce their kind by vegetative methods and make relatively little response to grafting, budding, etc. The number of plants which make no response to the grafting knife when in the hand of the skilled horticulturalist is probably small and relatively inconsiderable.

Neither does there seem to be any rule or order as to family relationships which might enable one to relegate all plants easily capable of vegetative reproduction into a class distinct from those which are more conservative in their reproductive methods. The tomato and the potato, both very important food plants, belong to the same plant family. The former, being cultivated for its fruits, is successfully grown from seed only; whereas the latter is cultivated for its underground stems (tubers) in which so much good food is stored, and these tubers are the so-called "seed" potatoes. Anyone who has observed vegetable gardens has remarked the close resemblance between the flowers (blossoms) of the potato and the tomato. The fruits of the potato when they mature as they sometimes do, are small greenish-yellow berries not greatly unlike tiny tomatoes and contain seeds very similar to those of the latter. Propagation from seeds in the potato is impractical and unnecessary. Experiment[3] has shown, however, that a tomato may be grafted on a potato plant or on a tobacco plant successfully. On the tomato grafted to the tobacco plant, in turn was grafted Solanum nigrum, Solanum integrifolium, and also Physalis alkekengi. All of these plants belong to the same family, namely, the Solanaceae or Nightshade family.

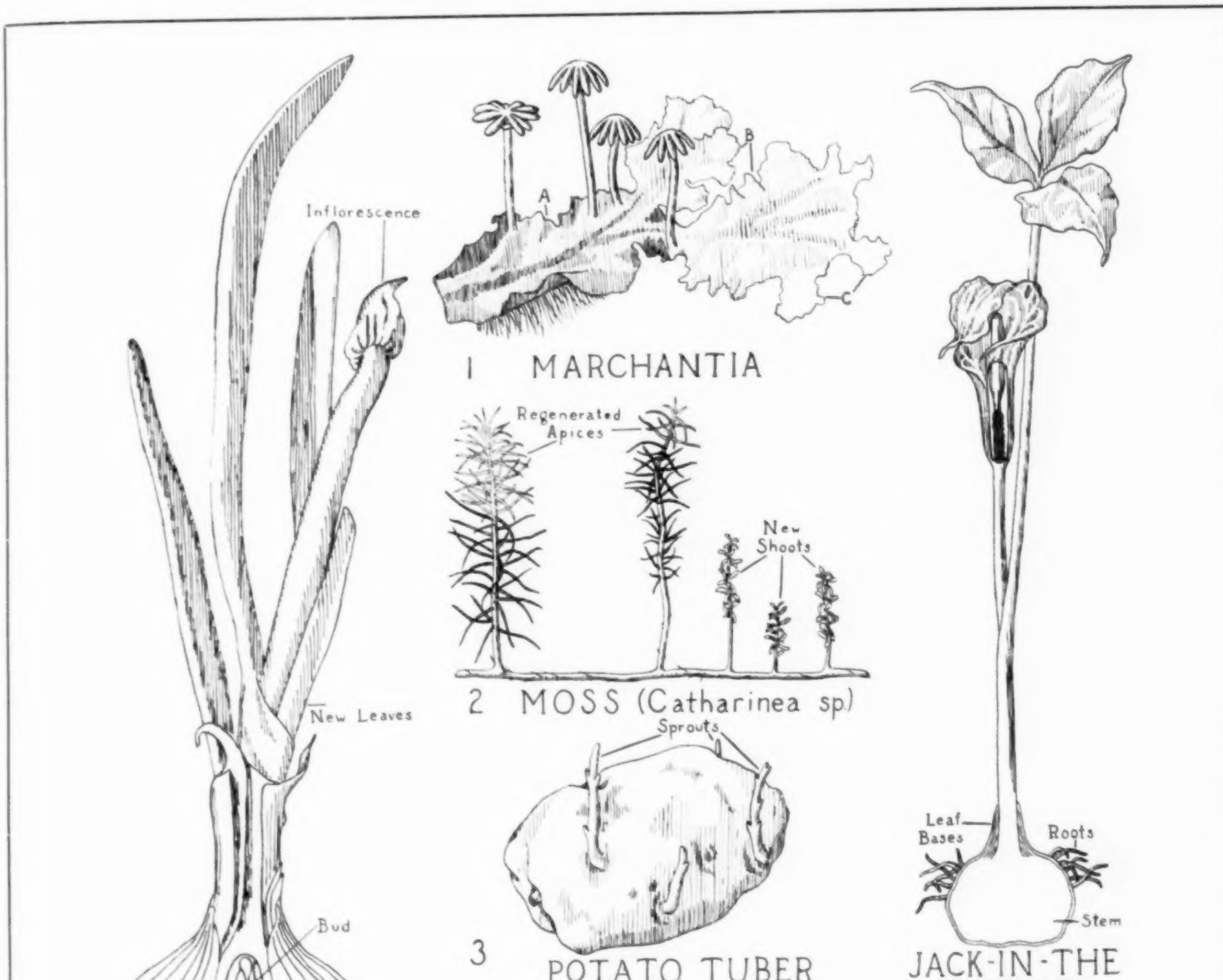
The number of plants which may be readily propagated by vegetative methods as well as by their seeds is very great. For example, many of our fruit trees and vines readily respond to both methods. For this reason, such forms have yielded to experimentation so as to enable a Burbank to "create" marvelous varieties. Again, there are those wonders among the seedless varieties of Citrus fruits, grapes, bananas, etc., known as parthenocarpic fruits which can and, in the absence of seed must, be propagated by vegetative methods, and this for the very seedless fruits which they bear.

VEGETATIVE REPRODUCTION IN NON-VASCULAR PLANTS

Vegetative reproduction is so general and so common among the Thallophytes that we shall omit them from this discussion and begin with the common representative of the liverworts, Marchantia polymorpha. This species can ordinarily complete its life cycle, that is, go from spore to spore, each year besides exhibiting the more common methods of perpetuating its kind by the simple dichotomous branching of the thallus and the special asexual means of developing gemmae as referred to above. Figure 1 shows the thallus bearing archegoniophores in which the spores are ordinarily ripe before midsummer; this maturation of spores is uneven, not only in a given head but also in the several heads, thus extending the season for spore dispersal in this species to a month or more.

After spore dispersal, the thallus continues to grow at the apex and the figure shows new branches (B) anterior to the archegoniophores, the foremost of the latter marking the apex of the thallus at the time of spore dissemination. The thallus in the figure was brought indoors toward the close of the growing season and, after some rehabilitation, the irregular proliferations marked C at the tip were the results of its response to a warmer temperature though less favorable conditions of illumination.

Mosses make similar responses to changes in temperature which favor regeneration of new shoots as Figure 2 shows. Indeed, there are many of the common mosses which never "fruit", either because they are dioecious forms or because the necessary water supply for dissemination of the spermatozoids is wanting at the season when this should occur. Thus, we have only repeated regeneration of the old thallus with a spread, due to the protonemata, which behave much as do the stolons and suckers in some seed plants. The figure of Catherinea sp. shows regeneration of new shoots at the apices of the old ones, as well as new upright shoots or gametophores. The method by means



Inflorescence
A
B
C
1 MARCHANTIA
Regenerated Apices
New Shoots
2 MOSS (Catharinea sp.)
Sprouts
3 POTATO TUBER
New Leaves
Bud
Leaf Bases
Stem
New Roots (adventitious)
4 ONION
Leaf Bases
Roots
Stem
5 JACK-IN-THE PULPIT
New Shoots
Stem
Roots
6 RHIZOME OF IRIS (Stem)
Verna Schultz

of which moss gametophytes may spread explains why mosses are always found in patches of considerable extent if only the habitat is at all suitable.

VEGETATIVE REPRODUCTION IN VASCULAR PLANTS

All ferns and their allies, as well as all seed plants, are commonly included in a single group on the basis of their complex and very efficient water and food conducting elements known as their vascular systems. This general class is known as vascular plants. The stem is the plant organ *par excellence* which displays this elaborate system for the conduction of water and raw materials from the roots, where the latter are absorbed, to the leaves and other green parts where carbohydrate food is manufactured and later distributed for further elaboration or for use or storage in other plant parts. The stem is the medium for all this traffic and it is the stem, too, in all of its many forms and manifestations, whether woody or herbaceous, annual or perennial, underground, aerial or aquatic, whether erect, prostrate or climbing, that is notably active in vegetative propagation.

SUBTERRANEAN STEMS

Of the subterranean types of stems, the potato tuber, (Fig. 3), the onion (Fig. 4) or lily bulb, the corm of the jack-in-the-pulpit, (Fig. 5) or of the gladiolus or the crocus, and the rhizome or rootstock of the iris, (Fig. 6) most of the common ferns, the may apple, the wild ginger and a host of other herbaceous plants, illustrate the potency of these specialized stems. These subterranean stems are not only capable of surviving cold and other adverse conditions but, because of their latent buds and an abundance of stored food, they are able to nourish the young plants they initiate and, in the case of the bulbous varieties especially, they are able to flower early in the springtime and long before the food manufacture of that season could possibly warrant it. That is, the inflorescences are supported by the food provided by the parent plant of the preceding season.

AERIAL STEMS

Of the aerial stem types, the stolons and runners, prostrate stems, situated above the soil, are exemplified by the strawberry and the cinqfoil, the moneywort (Fig. 7), the wandering jew and many others. All species of coleus (Fig. 8), geraniums and many others, illustrate the propensity to develop adventitious roots at the nodes of their stems if the water stimulus is sufficient. Small slips of any of these plants, when placed in a glass of water, will quickly respond if the light and temperature conditions are correct.

Many woody plants among the perennials, such as the willows (Fig. 9) and the poplars, afford splendid material for illustration of their propagative power. It seems certain that the twigs of the black willow, when broken off by the wind and carried down stream, become anchored on muddy banks. These take root and grow, thus making this species one of the most aggressive trees in such places. Willows may also be propagated by seeds and what applies to the general cultural aspects of willows applies to poplars as well. Certain of our more decorative trees and shrubs such as the sumac, the devil's walking stick (club of Hercules), and the ailanthus are found in clumps because of their ability to spread by underground structures which are called suckers. Thus, there results the huddled grouping of these shrubs or trees so conspicuous for their interesting foliage and fruits.

Certain woody stems in a horizontal position and in contact with the soil, such as blackberries, raspberries and the flowering shrub, forsythia (Fig. 10) demonstrate the process called layering, by simply sending roots and shoots from their drooping branches which have made contact with the soil.

ROOTS

Roots are generally anchored to the soil even in the case of many aquatic plants, and all types of roots, whether fleshy or fibrous, show a strong tendency to initiate new growths. The sweet potato, like the dahlia has fleshy fibrous roots which readily reproduce whole young plants if only the stimuli of water and sunlight are supplied (Fig. 11). The tap root of the dandelion remains in the ground and sends up aerial growths in succeeding years (Fig. 12). This annoying weed has still another insurance of its perpetuity because of its very numerous one-seeded plumed fruits, which by the way, are parthenogenetically developed. It is safe to say that wherever roots are fleshy and if climatic conditions are favorable to the species, such plants are able to propagate themselves vegetatively, using much of the food thus stored to meet the expense of flower, fruit and seed development. The common garden parsnip, if left in the soil all winter will send up new growths the second season terminating in flower and seed development, this plant being a biennial.

LEAVES

Comparatively few plants have leaves so constructed as to enable them to bud off new plants from their foliaceous tissue. Conspicuous among them (Fig. 13) is the walking fern (Camptosorus rhizophyllus.) The slender, much elongated leaf of this fern, when it makes contact with the soil, sends out roots and entire new plants which may become detached or continue in a series of growths, giving this interesting fern its very appropriate name. Bryophyllum (Fig. 14) and begonia are good examples of seed plants which show this type of vegetative reproduction. In bryophyllum these new growths, real plant progeny, may issue from any part of the leaf margin on either the dorsal or the ventral surface.

TISSUES ACTIVE IN VEGETATIVE REPRODUCTION

The initial tissue in leaves which are propagative is meristematic parenchyma. Stem and root meristem are active in various plants, especially the herbaceous forms, and in all woody forms which have no cambium. But in the woody perennials as illustrated here by the

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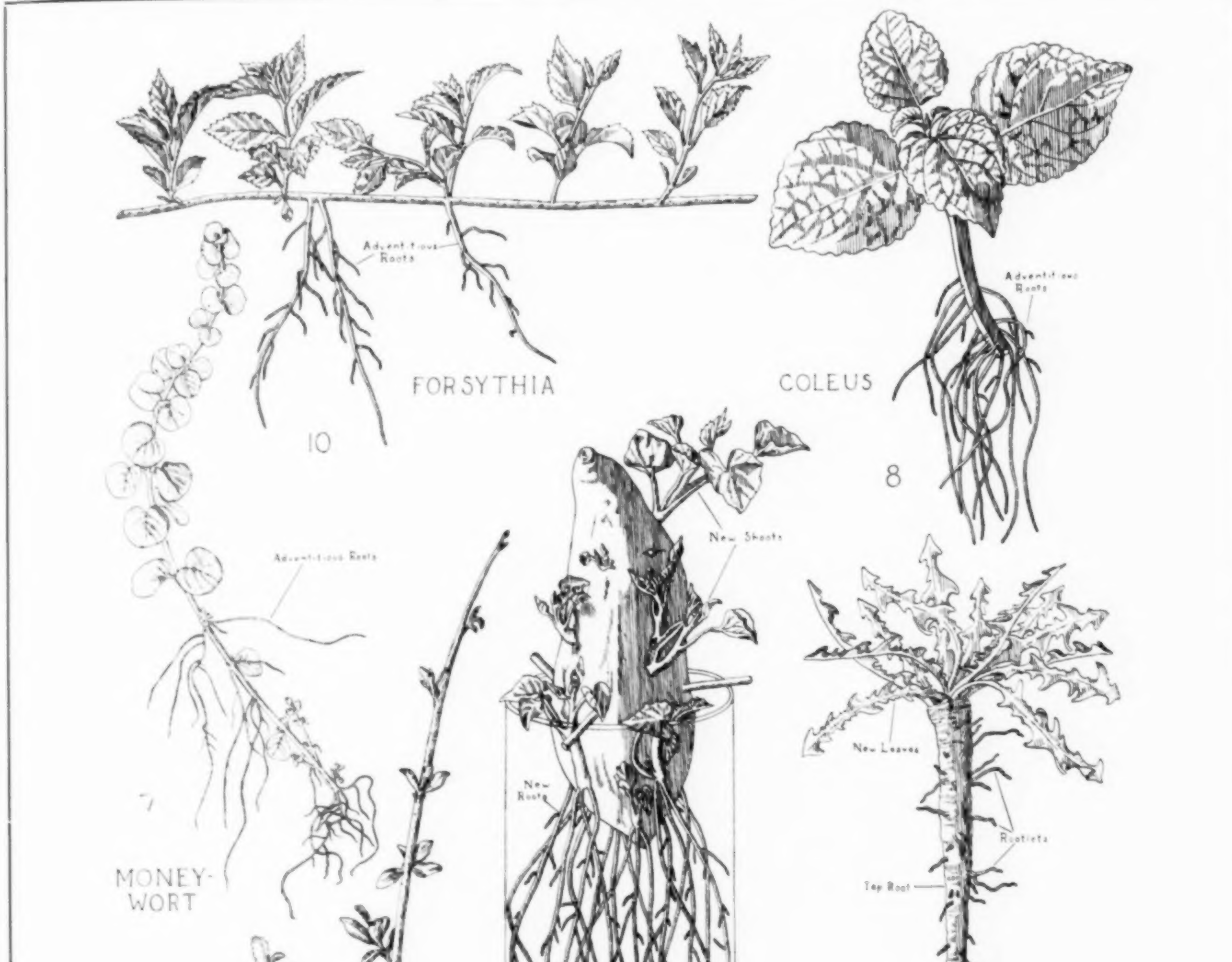
Adventitious Roots
FORSYTHIA
10
Adventitious Roots
COLEUS
8
New Shoots
Adventitious Roots
7
MONEY-
WORT
New Roots
New Leaves
Rootlets
Tap Root
12
DANDELION
Young Plant
Old leaf
Bud
14 BRYOPHYLLUM
11 SWEET POTATO
Adventitious Roots
9
WILLOW
13
Young Plant
WALKING FERN
Verna Schultz

The Scientific Care of Shade Trees

• By Paul Davey
EXECUTIVE VICE PRESIDENT, DAVEY TREE EXPERT COMPANY, KENT, OHIO

You will be interested in this article.

Mr. Davey tells how the scientific study of trees has brought about new and better methods for their care and protection. He discusses the value of microscopic studies and the necessity for a knowledge of soils. He explains why all insect enemies of trees cannot be destroyed by the same method.

Mr. Davey knows trees.

•

In the constant warfare which mankind wages against the forces of the unknown, striving always to attain the knowledge which will advance civilization and human welfare, the shock troops are composed of that great force of men and women engaged in the various branches of science. Often hidden from public view, their patient and persistent efforts represent the most tremendous forward movement of our whole civilization.

Not so many years ago the ordinary man considered the pursuit of scientific knowledge a purely intellectual avocation which might be of prime interest to those who were equipped for it but which meant little to the affairs of everyday life. In this day, however, science is making so many direct contributions to the production and preparation of our foods, to the treatment and prevention of disease, to the building of our homes and to our modern conveniences of transportation and communication that even the man in the street is beginning to realize what science means to him.

We who are devoted to the preservation and treatment of trees feel a particular debt of gratitude to the scientist, because it is he who has made our modern methods of tree care and protection possible and effective.

Since the beginning of history the tree has been one of the most valued friends of mankind. As a forest resource it gave him the timber with which to build his first ships, and made it possible for him to emerge from a cave and live in a house, even though it might be but a brush shelter or a log cabin. The tree has sheltered him from the elements, shaded him from the midday heat and contributed to his food supply. But he knew little about it. When a blight stripped the foliage from the branches he was without the grateful shade to which he was accustomed, but there was nothing he could do about it, because he did not know what had really happened. When the fruit crop upon which he depended for food failed to ripen, he could only attribute his misfortune to some force of nature which he did not understand. Even when men began to have some understanding of their own ailments and at least a rudimentary knowledge of methods of treatment or cure, they still did not suspect that the tree might also be suffering from disease or other attack for which there might be remedies or preventives.

Science has changed all this. The microscope has been used with truly amazing results. We now know the minute cell structure of the tree and understand how it lives and breathes, takes in its food, and distributes it for growth. Chemical analysis has shown us the composition of the food and the changes which take place as it is drawn up from the soil, exposed to light and air in the leaf, and passed on to the woody structure. Chemical analysis has also permitted us to penetrate the earth, assay its constituent mineral salts in their relation to tree food, and prepare to supply deficiencies which exist.

The microscope, too, has enabled us to study the lives and habits of the hordes of insect enemies which attack our trees, that we may destroy them before they destroy the trees on which they feed. We have been enabled to distinguish the line which separates insect life from the parasitic fungous growths which are spread by windborne spores, and, tracing the life processes of each, we have learned what to do about many of them.

A tree is a living, breathing organism. Physically to compare a tree with a man sounds absurd, because the great size and strength to which many mature trees attain makes a man seem but puny; yet there are many purely physical points of similarity. A tree must have food and drink and air to breathe. It takes its food in through its roots and the food must be in soluble form, because there is no provision for mastication. But the leaf, with the aid of air and sunlight, performs almost the same function that the human stomach does, in turning the raw food into a form which can be assimilated by the structure in growth.

One source of the tree's great strength, the manner in which it is firmly rooted in the ground so that it may withstand the onslaughts of the elements, is at the same time a weakness. The tree cannot move about from place to place in search of food and water as a man does or as lower members of the animal kingdom do. It is doomed to stand where its seed first sprouted, unless man intervenes, and if the food elements or moisture are lacking in that spot the tree cannot live and grow.

In this one fact is found one of the greatest contributions which science has made to tree care. It is now possible to analyze the soil in the root area of an ailing tree, to determine whether the necessary mineral elements are there. Many thousands of trees which in former years

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Program Planning and Preparation of Outline of Work for the High School Sciences

● By Merritt J. Fields, M.S.
DEPUTY STATE SUPERINTENDENT AND STATE DIRECTOR OF HIGH SCHOOL SCIENCE, BEAUMONT, TEXAS.

Long-range program planning as well as detailed daily teaching plans are necessary if the objectives of science teaching in high schools are to be attained satisfactorily.

Deputy State Superintendent Fields has given much thought to the planning of instruction in science, especially as it applies to the schools of his state.

His discussion will be helpful to teachers and executives. So also will be the outline of a teaching unit in general science actually in use in a Texas high school.

The subject under discussion is of such importance to success in the teaching of science in the high schools that we must necessarily take into consideration the entire science curriculum. No worthwhile planning may be accomplished until the science program is seen and understood by the teacher in its entirety. The broad concepts, philosophies, aims and objectives in the whole field of science teaching and the application of science in the world about us must enter into the development of any plan which may be considered as worthy. Curriculum revision of a continuous nature must be provided for if we are to have a dynamic program instead of a static one. In fact, science itself is so dynamic that, although it may become stifled somewhat by adverse teaching, it can never be made entirely static. The teaching obligation is to aid the dynamic exploration of the vast field covered by the sciences, and in no way to assist in its exploitation nor hinder its progress. The teaching merely of what has been accomplished in science, although important, is certainly far short of the ultimate goal. Rather should we be concerned with how to develop in each student a scientific attitude or an inquiring mind.

It is interesting to note that, according to Mr. Carl A. Jessen, Senior Specialist in Secondary Education in the National Office of Education, statistics reveal a gradual downward tendency in the percentage of the total enrollment of students taking science subjects in the high schools during the last forty years. These same figures show that in 1934, 38.8 per cent of the total number of pupils enrolled were taking general science, biology, physics and chemistry. General science, which was offered in 71 per cent of the secondary schools and which was taken by fifteen per cent of the pupils enrolled, was easily the leader in the science taught, and had been during the last fifteen years. From this same report it is also found that in 1928 only 291 secondary schools in Texas were offering general science, with an enrollment in the classes of 10,552; while, in 1934, there were 689 such schools in Texas offering this subject with a class enrollment of 27,741.

Thus, we see a need for program planning and for the preparation of outlines for teaching the high school sciences. This discussion is in no way concerned with the mere preparation of syllabi. It has a much broader meaning. It is our purpose to suggest a more definite type of planning than is ordinarily contained in a syllabus. In our study of this problem the entire science program should be seen as a continuous whole, which will take into account the child's study and experience in science during his sojourn in the elementary grades. The program in the high school should provide for a progression of the child in the further development of a scientific mind, as well as in scientific knowledge.

Our philosophy in planning should: (1) develop the scientific or inquiring mind in such a way as to harmonize with desirable human emotions; (2) secure reasoning, guided by the best standards yet dictated by human emotions, and now in common practice.

The development of the mind separate and apart from the desirable human emotions may cause the individual to become cold, calculating, and shrewd. This type of mind may, perhaps, be efficient in scientific knowledge, but it is certainly devoid of the humanizing effect which science should give, and will be lacking in humanitarianism. The study may become too theoretical rather than sufficiently practical, or it may fail to carry the necessary application. Aspiration and inspiration may well be major objectives in each course in high school science, if we would establish the traits of character to which these subjects admirably lend themselves.

A study of general science should be recognized as an instrument for a more definite understanding of the world about us; the social order should unfold in greater simplicity, and participation in its benefits should become more satisfactory and meaningful after the completion of the course. Biology should give the student a broad concept of life, and a fund of information which will enable him to understand and adjust himself to the environment in which he lives. It should lead him to a study of the problems of health; of the conservation of our natural resources; of the inter-dependence of life; and of the improvement of the race through high ideals of living. A study of the common insects, birds, flowers, trees, soils, rocks, plants, and animals should lead the student to a greater appreciation of the wonderful blessings of nature, and to an acceptance of the Supreme Architect of the Universe. Physics and chem-

istry should come to solve many of the world's perplexing problems, and the teaching objectives should be toward this desirable goal.

The most noticeable criticism of much of our teaching of science courses in the high schools seems to be that we are trying merely to make technicians in science out of our students. Would it not be better to seek results in the form of preparing the individual for fuller and richer experiences in the life which he must necessarily live and have being? Mass teaching of the sciences can not justify itself in the development of technicians alone. Such a presumption would be that the work is offered chiefly for the very few who may become outstanding in some phase of science, or for those who may choose this field as their vocation in life. What about the other ninety per cent? Neither are college entrance requirements sufficient criteria for the establishment of objectives and goals for the science courses. The well-trained, understanding, and sympathetic teacher is largely the key to success in the development and use of a suitable program and of an adequate teaching plan for these subjects.

The great need for individual teacher planning of the science program and the preparation of units of instruction were made more evident to the writer upon examining numerous state courses of study in science from various parts of the Union, particularly those known to have a state-wide program of curriculum revision under way or completed. This study has been continued over the past three years, with the purpose of determining their usefulness to the teacher in teaching the science courses. The conclusion has been reached that they are all helpful, but quite inadequate for exclusive use by the teacher. They are, ordinarily, too wordy. It would require too much of the teacher's time to locate the desired help. However, these courses of study are invaluable as guides by which the teacher may prepare her written program and the outline of her annual and daily teaching plans. Only through the teacher-made program may the child be made the center around which the activities of the courses shall operate. Thus, the common practice of forcing every child to fit one pattern, which is often devised with little regard to the best interests, aptitudes, and individual differences, may be avoided. The teacher might well use some of the best courses of study, and other prepared materials for securing excellent suggestions and ideas, but it is hoped that she will take up where these leave off and reach out beyond the horizon contained in them. Her purpose should be to devise a plan which will provide for richer and more useful experiences of the students in her science classes.

We realize, all too well, that many teachers of science do not undertake the tedious and laborious job of preparing a written annual teaching plan; neither do they use a daily written plan of their own making. It seems to be customary to follow rather religiously state courses of study and textbooks, laboratory manuals, and syllabi handed out by superior authority, and prepared workbooks. All of this array of materials is helpful and rather essential as guides and for references, but when used exclusively and slavishly it falls far short of accomplishing the desired results.

Much has been said regarding the program in general. Now let us consider the detailed preparation of the teaching plan. To prepare the most worth-while plan will require the making of a chart or graph at the very outset. It should be a skeleton outline of the subjects and units to be included in the year's work. It will then require only a glance from the teacher to keep her informed as to what is to come next. The circular-graph is very convenient for this purpose, as we have observed its use in the Stephen F. Austin high school, Port Arthur, Texas. This form of graph should be drawn to a convenient scale of degrees, measuring the time to be devoted to each topic or unit to be studied, and numbered as to sequence of their appearance in the course. From this outline or graph of the year's work may be developed a plan which, when sufficiently revised and cast in its final form, should be either mimeographed or printed for use. The detailed plan should make provision for a fly sheet, a table of contents, and an introduction in which the aims, objectives, and goals for the course are established. It should be divided into convenient teaching units which are arranged in proper sequence for accomplishing the results which are to be achieved. Only a few well chosen and most important units of work should be undertaken in each semester.

The following outline of a teaching unit in general science for the eighth grade, as used in the Austin high school, Port Arthur, is given here to illustrate our point. Perhaps it will offer helpful suggestions to the teachers of science who may desire to avail themselves of the opportunity to try this form of planning.

UNIT IV

Matter and Its Changes

Ultimate Objectives:

1. Ability to understand that things about us are composed of matter that is measurable and subject to change.
2. Ability to appreciate the fact that matter is composed of small particles which have varying degrees of attraction for each other.
3. Ability to understand that matter may undergo changes, but that elementally it remains the same.
4. Ability to understand that every reaction has some cause.
5. To acquire an interest in phenomena that occur in the material world.

Unit IV. Problem Sheet

Unit Problem: Nature of matter and changes it undergoes.

Problem I: Nature of Matter.

Sub-ideas:

1. Matter is anything that occupies space and has weight.
2. The smallest divisions of matter are known as atoms and molecules.
3. Matter may take the form of a solid, liquid, or gas.
4. Matter may be an element, compound, or a mixture.

Problem concept:

The world in which we live is made up of matter, and the amount of matter is unchangeable, although it may change its form or composition.

Problems II, III, IV, etc., follow in order and are worked out on very much the same plan as the problem given in detail above.

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Atmospheric Electricity And Lightning

• By William A. Lynch, Ph.D., *(New York University)*
PROFESSOR OF PHYSICS, FORDHAM UNIVERSITY

Professor Lynch here completes his study of the electrical phenomena of the fine weather field, which was begun in our December, 1937, issue. He then considers the earth's field in stormy weather. His discussion of lightning contains information that should be of interest to all.

The appended bibliography will be helpful to those whose interest has been aroused by these scholarly articles, and who care to continue the study.

●

PART II

Special methods have been devised for measuring the potential gradient at great heights by means of kites and balloons. The results are not very precise but they all indicate a decrease in the magnitude of the potential gradient with increasing height so that at approximately 10,000 meters, the field has only 1/50 of its value at the surface of the earth. This shows that there must be a free positive charge in the atmosphere below a height of say 15 kilometers, equal to the entire negative charge on the earth's surface, i. e., 500,000 coulombs; for all the lines of electric force that terminate on the earth must have originated on plus charges in the atmosphere. Experiment shows that above a height of about 15 km. the potential remains constant; hence, the region above 15 km. may be looked upon as a conductor with a positive charge on its lower surface, from which lines of force extend to the earth. The potential difference between the earth and the air at 15 kilometers is of the order of 10^6 volts. It is often assumed, because of the great conductivity of the atmosphere at greater altitudes, that this is also the potential of the Heaviside layer 80 km. or so above the earth.

The fine weather field, with its potential gradient of approximately 100 volts per meter near the surface of the earth, is responsible for the continuous fine weather current of positive ions downward and negative ions upward. At the same time there may be a mechanical transfer of ions by the wind or convection currents in the air; this results in what may be called a convection current of electricity. The sum of these two components gives the true fine weather current which amounts to about 2×10^{-16} amperes per sq. cm. or 2 microamperes per sq. km.; that is, about 1,000 amperes for the whole earth. The fine weather current can be measured by an extension of Wilson's method with metal plate and electrometer. The plate is exposed to the earth's field and the time required to charge up the electrometer is taken; the rate of charging of the plate is a measure of the current flowing to the surface of the earth.

THE EARTH'S FIELD IN STORMY WEATHER

In stormy weather, the electric field of the earth is quite different from the fine weather field and new components of the air-to-earth current appear. The field may be directed upward during a steady rainstorm; this may also occur during extended dust storms, at the same time that the potential gradient reaches the large value of 10,000 volts per meter. The field may be positive or negative during heavy rainstorms and thunderstorms, depending on the situation of the storm clouds with respect to the observing station. In thunderstorms, the potential gradient may reach 50,000 volts/meter, although usually its value lies between 10,000 and 20,000 volts per meter. The field is positive during snowstorms, the gradient reaching values of the order of 10,000 volts per meter.

The different forms of precipitation carry electric charges to the earth, the sign and magnitude of the charge depending on the nature of the storm. Rain usually carries a positive charge to earth. Thunderstorm rain is positive if it comes from the front of a thunder cloud, but negative if it comes from other parts of the cloud. A fine drizzle carries a negative charge, while snow is strongly negative. The results of long series of observations on these "precipitation" currents, particularly by Simpson in India, show that a positive current flows from the atmosphere into the ground, in the same direction as the current of fine weather. This current is from 10^{-13} to 10^{-12} amperes per sq. cm., but may reach the value of 2×10^{-11} amperes per sq. cm. during a heavy thunderstorm, the total current carried by the rain then reaching the value of about 0.1 ampere. These measurements are made in a very simple and direct way. The rain or snow is caught in an insulated metal can to which an electrometer is connected. The electrometer registers the total charge collected in a given time, while the rate of charging gives a measure of the precipitation current.

A second type of flow occurs during stormy weather particularly when the earth's field reaches large values. Trees, bushes, and grass act as sharp-pointed conductors, and the familiar brush discharge occurs. This type is observed on a large scale under thunder clouds and is known as St. Elmo's fire when visible as a flame-like discharge from the masts of ships. Schonland measured the discharge from a small tree, about 12 feet high, during a nearby thunderstorm. The tree had been cut off at its base, carefully mounted on insulators and connected to the ground by means of a galvanometer. The current varied from 0.07 microampere in a field of 3,500 volts/meter to 4.00 microam-

peres in a field of 16,000 volts/meter. He estimated that the trees directly under the cloud supplied a total point-discharge current of about two amperes from earth to cloud.

Wormell at Cambridge, England, used a very clever device for finding the total brush discharge from an elevated point over a long series of time. He connected a water voltameter in series with the discharge point and the ground, and collected the gases liberated by electrolysis for three successive years. He found that a net positive charge of about .13 coulomb was liberated yearly from the single point. The excess of positive electricity discharged in the upward direction shows how important the reversed electric fields of stormy weather are in determining the transfer of electricity between earth and atmosphere. Much more information of this type is desired from different parts of the world.

We have studied three different processes by which electricity is carried between the ground and the upper air: the fine weather current, the precipitation current, and the discharge from points. The first two cause a transfer of positive charge from atmosphere to earth tending to neutralize the negative charge there; the third takes positive charge from the earth and gives it to the atmosphere, thereby partially replenishing the earth's negative charge. The replenishment is consummated by the action of a fourth agent that is the most fascinating of all, the lightning discharge. We know the earth remains negatively charged. A balance must be struck between the rate of flow of charge upward and the rate of flow downward so that the state of equilibrium is not destroyed. It was C. T. R. Wilson who first showed the effectiveness of lightning in maintaining the balance.

LIGHTNING

In New York City we have frequent thunderstorms during the summer months, but many months pass in a year during which no thunderstorms occur at all. However, the average number over the whole earth at any instant has been placed at 1,800, with approximately 100 lightning flashes every second. The power expended continuously in these storms is almost unbelievable, amounting to $4\text{x}10^{\text{[illegible]}}$ kilowatts. By way of comparison, the maximum power developed at Boulder Dam is expected to be about $1.5\text{x}10^{\text{[illegible]}}$ kw. The average charge of electricity carried by each flash is about 20 coulombs and the average current about 20,000 amperes, although there is evidence to show that the lightning current may reach 250,000 amperes. As a flash develops, the difference of potential between cloud and ground is estimated to be about $2\text{x}10^{\text{[illegible]}}$ volts. The total heat liberated during the flash is approximately $5\text{x}10^{\text{[illegible]}}$ calories, sufficient to melt about 60 tons of ice. These facts about lightning have been well established by observation and experiment. The mechanism by which the thunderstorm operates, however, is not so well understood, although many theories have been formulated to explain it. We shall proceed to a study of the mechanism and the principal theories that have been advanced.

A thunder cloud differs from an ordinary rain cloud in two important particulars: it is much more extensive in the vertical direction, and at the same time is subjected to powerful convection currents of air sweeping upward through the body of the cloud. These two factors permit very rapid condensation and precipitation of moisture with the liberation of sufficient energy to separate large quantities of positive electrical charge from negative charge. The strong, upward air currents result whenever there is high relative humidity in the lower atmosphere accompanied by a rapid decrease in temperature from the lower to the higher regions of the atmosphere. These conditions occur, for instance, in the temperate zones when there is strong surface heating of the earth on a clear, sunny day in May or June before the upper air has reached its normal summer temperature. Simpson and C. T. R. Wilson have advanced theories that account for the separation of the electrical charges in the cloud at the expense of the energy of the upward current of air. They arrive at different results, but each has experimental evidence to support his argument.

Simpson contends that the plus charges of electricity are separated from the minus charges by the breaking up of raindrops as they fall through the air stream rushing upward in the cloud. His experiments in 1908 showed that when large water drops break up into small drops in an air stream, they acquire a positive charge and the air carries away a negative charge. The largest drop that can fall through air without further breaking up has a diameter of 0.5 cm. and falls at a maximum rate of 8 meters per second relative to the air. Rain, therefore, cannot fall through a vertical air current which moves at a greater velocity than eight meters per second. Simpson assumes that immediately below the storm center of a thunder cloud, the upward velocity of the air is greater than eight meters per second. Large drops falling toward the storm center from the upper regions of the clouds are broken into droplets with a positive charge; the air stream continues upward, carrying negative charge to the higher parts of the cloud. Simpson concludes that the lower region of the thunder cloud is positive and the upper negative, and that the lightning stroke carries positive charge to the ground. He collected 442 photographs of lightning flashes from all sources and observed that 242 showed branching of the stroke away from the thunder cloud, while only 3 showed branching toward the cloud. He then performed a long series of laboratory experiments on sparks and found that branching always occurred away from the positive electrode. He felt satisfied that his explanation of the mode of separation of the charges above the storm center was correct.

Wilson measured the charges in the electric field at the ground during a great number of thunder storms by the general method described above. He found that the lower parts of the thunder cloud were negative and the upper parts positive, just the opposite to Simpson's assumption. His theory is based principally on this experimental fact and is somewhat as follows: he

assumes that the field as he measured it is already in existence, directed downward inside the thundercloud. This causes the positive ions to move downward and negative ions upward; but only large ions with small mobility (.0003 cm/sec. per volt/cm) can exist within the cloud because of the numerous condensation nuclei. Macky has found by direct experiment that disruptive ionization occurs in air laden with water droplets of the size found in thunder clouds when the field intensity reaches a value of 10,000 volts per centimeter. Hence, Wilson contends that greater fields than this cannot exist inside a thunder cloud so that the velocity of the large ions in the cloud cannot exceed 3 cm/sec. relative to the air. This is the rate at which a water drop 0.1 mm. in diameter falls through air under the action of gravity. All drops with radii greater than 0.1 mm., therefore, descend more rapidly under gravity than do the large ions under the action of the electric field in the cloud. The neutral water drops falling through the electric field have charges induced upon them, negative on the upper and positive on the lower surface. Consider the behavior of one large drop of radius about 1 mm. that falls with a velocity of a little less than 6 meters per sec. relative to the air. This drop overtakes positive ions moving down the field, but repels them because of the positive charge on its lower side; but it attracts and collects negative ions moving up through the field. The drop does not pick up positive ions in spite of the negative charge on its upper side because of its rapid rate of fall with respect to these ions. Large drops acquire perceptible negative charges in this manner and build up a large negative charge in the lower regions of the thunder cloud. At the same time, the air stream carries the positive slow ions upward to the top of the cloud. This mechanism can only build up a field within the thundercloud that already exists there, the normal fine weather field. The final result with respect to the ground, however, is a reversal of the field so that the ground directly below the thundercloud is positive, and negative electricity is transferred to the ground by the lightning flash.

Evidence is accumulating that in the majority of cases negative electricity is transferred to the ground by lightning. Recent measurements by German electrical power companies are particularly informative in this respect. They used a form of magnetic detector close to a transmission tower or lightning conductor. The detector consists of a short bundle of iron wires sealed in a test tube. When the tower was struck, the magnetic field of the discharge current magnetized the wires, and the residual magnetism of the iron was a measure of the maximum current. About 24,000 of these detectors were distributed in 1934. The results showed that the discharge currents were usually between 30,000 and 40,000 amperes; currents greater than 100,000 amperes rarely occurred. In 97% of the cases examined, negative electricity was discharged to the earth. This is strong support for Wilson's view of the thundercloud mechanism, but it is probable that the actual series of events preceding the lightning flash is more complicated than asserted by Simpson or Wilson.

THE LIGHTNING FLASH

Lightning flashes have been studied intensively in the last few years by the photographic method with moving cameras. The best work has been done with a type of camera devised by C. V. Boys. He built a camera, in 1902, with two lenses about 4 inches apart rotating at opposite ends of a diameter at a maximum rate of 40 r.p.s. By this means the two images of a flash would be carried in opposite directions, and Boys felt that he could obtain detailed information about the nature and propagation of the flash. He carried the camera for twenty-six years before he finally obtained a picture at Tuxedo Park, New York. Schonland and his colleagues in South Africa recognized the potentialities of the Boys' method and have developed it to a high degree of precision. They have succeeded in photographing 65 flashes, and have shown that almost without exception lightning flashes are intermittent in character. In fact, there were 235 separate strokes in the flashes they caught.

Schonland's study of the photographs has yielded the following description of the composite lightning flash; the quantitative results are obtained from the speed of rotation of the lenses, the distance between camera and flash, and from measurements of the paired images on the photographic plate. Each flash is started by a "stepped leader stroke." This consists of a luminous streamer from the cloud towards the ground, which dies out after traveling only a small fraction of the total distance to the earth. A second streamer follows about 50 micro seconds later, traversing the same track as the first but elongating it from 50 to 100 meters. A third streamer follows the second by about the same interval of time and in the same channel, extending the track still further toward the earth. Each fresh addition to the path is very much brighter than the rest of the streamer. This process continues until a track is blazed all the way from cloud to earth. The average rate of progress of this leader stroke is about 10^7 cm/sec., although each streamer advances at about 1/10 the velocity of light. The leader is followed by the main or return stroke, which shoots upward from the ground to the cloud along the same trail blazed by the leader. The start of the main stroke occurs immediately on the arrival of the leader. The main stroke progresses at about 1/10 the velocity of light so that its time of passage is very much less than that of the stepped leader.

The first main stroke is followed by a second stroke which consists of a leader and a return, and follows the same channel as the first stroke. The leader in this case is not intermittent but continues in its passage from cloud to earth. Schonland terms it a "dart" leader. The time interval between the completion of the first main stroke of a flash and the beginning of the dart leader of the second stroke of the same flash is a few hundredths of a second. A third stroke fol-

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Educational Field Trips In Geology

• By Walter E. Hess
ADVISOR, SECONDARY EDUCATION, PENNSYLVANIA DEPARTMENT OF PUBLIC INSTRUCTION

What's good for pupils should be good for teachers.

Here is an account of conducted field trips in geology that are provided for teachers and others by a considerate state department of public instruction. Teachers of Pennsylvania are unusually fortunate in having such fine opportunities for making geologic surveys under expert direction.

Other states could follow this plan to advantage. Perhaps some of them are doing so. Why not suggest the idea to your own leaders in education?

•

For some unexplained reason, the operations of a geologist and the functions of a geologic survey appear to be enigmatic as far as public interest in general concerns itself. Appreciating this, but at the same time holding the belief that many of the citizens of the Commonwealth of Pennsylvania would welcome the opportunity to learn something about the principles of earth science and at least the rudiments of the geology of their state, the Pennsylvania Topographic and Geologic Survey inaugurated a scheme for furthering and distributing knowledge of the science to interested residents. Because geology is a study of the rocks of the earth's crust, and since rocks are to be seen almost anywhere in the State of Pennsylvania, what better means of spreading the gospel of geology could be found than taking people out and telling them about the rocks near their homes? Working on this theory, field trips have been conducted from time to time in various parts of Pennsylvania during the early fall and late spring months. The first of these educational trips was held in 1935.

The field trips have been arranged primarily for school teachers, particularly those holding instructing positions in the sciences in teachers' colleges and high schools. Nevertheless, anyone else interested in the subject is always welcome to participate. Many others besides teachers attend. A surprisingly large number of citizens have a genuine and keen interest in geology as an avocation, and to these as well as to science teachers, the trips seem to have a particular appeal. Not a few young people, boy and girl scouts, and students join in "to find out what it's all about." Occasionally, a teacher and his class attend *en masse*.

The trips are planned systematically and have been operated on close schedules. In order that the excursions might be well advertised to the public school faculties, a co-operative arrangement was made with the Pennsylvania Department of Public Instruction. Through the Bureau of Instruction of that department, contacts are always made some weeks prior to the date set for a trip. Teachers of science and other interested persons known to reside in the environs of a locality selected for that particular excursion are contacted. Notices describing the trip, and stating its time and place of departure, and other details are distributed to all those likely to attend.

The field trips themselves have been arranged, scheduled and conducted chiefly by Dr. Bradford Willard of the Pennsylvania Topographic and Geologic Survey, but often with the valuable co-operation of other staff members. Prior to announcing a trip, a region is selected and "gone over" thoroughly. Points of geologic interest are noted and the most advantageous route to follow is chosen. In every case the chief object or aim is to keep the trip as scientifically simple as possible, avoiding all unnecessary technicalities; for it is realized that, while some professional geologists occasionally attend, the majority of those who take part have had comparatively little, perhaps no, geologic experience. Each trip is so laid out that it can be covered by automobile in either one-half or a full day. Usually the trips are scheduled for Saturday. When a whole day is consumed, an appropriate lunching spot is selected. Participants bring lunches, and an impromptu picnic is enjoyed.

Those taking part in a particular trip assemble at the appointed place and at the specified time given in the preliminary announcement. Each visitor is then supplied with a mimeographed itinerary of the trip. These itineraries show mileage between all points, total mileage of the trip, stops, turns, cautions, times of arrival and departure from each station visited, and a brief statement of the geology to be seen at each stopping place. Appended to the itinerary is a summary of the local geology covered during the trip. Copies of the Pennsylvania Topographic and Geologic Survey Bulletin 113, "Pennsylvania Geology Summarized" are distributed gratis.

Because of the numbers attending and the length of the motorcades involved, trips are necessarily run on a precise schedule. By allowing ample time for each stop and for running time between stops, and by leaving all stations punctually, trips have always been completed on schedule time. This feature appeals particularly to the participants who have been obliged to come from some distance, because it assures them ample time for their return journey. The lectures are quite informal. Generally, at the start of a trip or at the first stop, a ten-minute talk which serves as a synopsis of what is to be seen on that particular excursion, is given. This functions also as an introduc-

(Continued on Page Thirty-one)

Some Biological Applications of the Elementary Principles of Physics

● By George E. Davis, Ph.D., *(University of Minnesota)*
DEPARTMENT OF PHYSICS, DUQUESNE UNIVERSITY

Don't miss this article!

Teachers of physics and of biology will find here some valuable information that is not to be found in most textbooks. It can be used to make the teaching of these sciences more objective and, consequently, more interesting.

Readers will be glad to know that Part II of this article will appear in another issue.

●

PART I

Without doubt the personal importance of the laws of physics to man has been stressed by every teacher of truly understanding mind who has been privileged to pass on to others his knowledge of this most fundamental and comprehensive science. Year after year it has been pointed out to classes in physics that every one of us lives daily in intimate contact with a physical world in which force and inertia and energy and momentum and all the other definable entities behave in accordance with certain unvarying laws; in which laws we, therefore, may well have a most real and personal interest. This is as it should be. We must continue to make physics more interesting to our students by pointing out the vital biological importance of its laws and principles in the universe in which we live.

But we should go farther than this. We should point out not only that we live *in* such a universe but that, in a sense, the universe lives *in us*. All the fundamental physical laws are obeyed as implicitly in our physiological reactions as they are in the motions or changes of temperature of an inanimate body. The apparent differences between the physical reactions of living and non-living things are superficial and are essentially differences only in degree of complexity. The laws of physics, therefore, are built into our very existence and into the existence of every living thing.

It is unnecessary for us, as physicists, to inquire whether man is not something more than a physical (and chemical) machine. He is more. But, as physicists, we deal with physical things only, not with things of the spirit or of the intellect. Physics explains how we see and hear, how we lift weights or stand erect or run, how we radiate heat or absorb it, how we talk and sing, the nature of our nervous impulses, and many other things that are vital to us. We should point this out to our students. By so doing we broaden their points of view and give them the best possible basis for an absorbing interest in the subject.

We shall describe some applications of the principles of physics which are to be found in the human body or in connection with other organic life. Only a few examples are given, out of a much greater number which will occur to the teacher. Those chosen seem not too difficult to be understood by the average beginning student of physics in high school or college. However, if any parts of the discussions appear to the teacher to be too involved for his class, he can omit those parts or, perhaps, put them in less technical language. It has been thought best to include in this discussion more on each topic than many teachers may care to use, rather than to include too little. Each teacher can choose from the material here given, or add to it, as he may desire.

USE OF LEVERS IN THE BODY

The skeleton is not merely a rigid support or protective shield for the tissues and organs of the body. Many of the bones are levers as well, by means of which a great variety of movements are executed. By use of these levers we walk, write, chew our food, breathe, play the piano, lift weights, swim, handle tools, paint pictures, build houses and perform all the other thousand and one acts which involve the use of arms, hands, legs, feet, back, neck, chest, shoulders and jaws. Even hearing involves the use of tiny levers of bone.

All three classes of levers occur in the body, but the third class is by far the most common. In this kind of lever the force of the contracting muscle is applied between the fulcrum (the joint) and the point where the resisting force is to be overcome. So far as force is concerned, this type of lever is least advantageous. Its mechanical advantage is always less than unity and, in the human body and the bodies of other vertebrates, usually very much less than unity. Therefore, the force exerted by the muscle is commonly many times as great as the resisting or "useful" force.

There are at least two reasons why nature has so built these living machines. The first and chief reason is that speed of movement is more important to vertebrates than is strength. Speed to escape from enemies, to catch prey, to win in combat, etc., is all important. Nature even went so far as to anticipate the need for speed in crossing Main Street! The second reason is that by attaching the muscles close to the joints, trimness and economy of space are attained. Think, for example, of an arm with the biceps attached at the wrist. Such an arm when flexed would be from 10 to 12 inches wide, measured from the elbow upward—a most ungainly appendage. It would be very strong, but, comparatively, also very slow of movement.

The bones of the arms, fingers, legs and toes are examples of third-class levers. Problems in finding the mechanical advantage, the force exerted by the muscle

and the ratio of speed of movement to speed of contraction of the muscle can be made up from the following data, which are roughly correct for the arm and leg, respectively, of the man of average size: Distance from elbow joint to point of attachment of biceps to radius, 2.0 in.; to point of attachment of brachialis (mucle adjacent to biceps) to ulna, 0.4 in., average, 1.2 in.; elbow joint to palm of hand, 13 in.; knee joint to points of attachment of muscles of upper leg which draw the lower leg backward (prominent tendons behind the knee), average, 3.3 in.; knee joint to bottom of heel, 20 in. The effective lever arms of the applied forces (joint to muscle attachment) are less than the figures here given when the arm or leg is straight or only slightly bent, since it is the *perpendicular* distance from fulcrum to line of action of the force which is effective. When the arm or leg is straight, the tendons lie close to the joint and the perpendicular distances are considerably reduced. When the arm or leg is bent at right angles, the figures we have given may be used for the lever arms of the applied forces.

As an example of the relationships between forces, speeds and distances, let us say that a weight of fifty pounds in the palm of the hand is lifted with the upper arm vertical and the lower arm horizontal. Assuming, for simplicity, that the biceps and brachialis muscles, which act together, exert equal forces. Their effective lever arm is 1.2 in. Therefore they exert a combined force of about (13/1.2)x 50 lb., or 540 lb. The distance moved by the weight is 13/1.2, or approximately 11 times the average distance moved by the muscles, while the speeds are in the same proportion. The mechanical advantage is only 1.2/13, or about 0.09.

Levers of the first class are not numerous in the body. The skull, resting upon the atlas at the top of the spinal column, is an example. This arrangement is used as a first-class lever when the head is nodded or when a load carried on the head is balanced by the pull of the muscles. But if one pushes backward or forward with the head, against a resisting force, the lever becomes essentially third class.

In levers of the second class the mechanical advantage is the greatest possible for a given total length of lever. Therefore nature has used this lever in the foot, where great force is needed to raise the body, as in walking, running, etc. The powerful muscle in the calf of the leg connects by means of the tendon of Achilles to the heel bone, at a point (foot of average man) about 2.0 in. from the fulcrum, which is at the lower end of the tibia, the larger bone of the lower leg. The distance from the ball of the foot to the fulcrum is about 5.5 in. But these points are not in a straight line, so the effective lever arms depend upon the position of the foot with respect to the leg. Let us consider the act of rising on the ball of the foot. When standing with the foot horizontal, the lever arms for the applied force (tendon to ball of foot) and the resisting weight of the body (fulcrum to ball) are approximately 6.5 in. and 4.8 in., respectively, giving a mechanical advantage of 6.5/4.8, or 1.4. When the body has been raised two inches, the effective lever arms are about 4.8 in. and 2.9 in., respectively, giving a mechanical advantage of 4.8/2.9, or 1.7. Thus the great force exerted by the muscle is made still greater in effect, to raise and support the weight of the body and any extra load which may be carried.

It has been mentioned that hearing involves the use of small levers of bone. This most interesting application of mechanics will be discussed in connection with the ear.

NATURE'S INIMITABLE CAMERA

In most textbooks of physics the eye is discussed very briefly in connection with the subject of light. Generally the discussions are entirely too brief to do justice to this organ, with its marvelous adaptations of the principles of optics to the needs of the living being. We, therefore, shall describe a little more fully the elementary principles involved.

The eye is a miniature camera. Corresponding to the glass lens, the shutter, the diaphragm, the aperture and the photographic plate of the camera are the crystalline lens, the eyelid, the iris, the pupil and the retina of the eye, respectively. In function and in action there is a close similarity between corresponding parts.

The best camera lenses are compound, being made of two or more single lenses of different refractive indexes, cemented together. Similarly, the lens of the eye is composed of a series of concentric layers, of which the index of refraction increases step by step from the outer layer to the nucleus. The purpose of this construction is the same as in the compound camera lens; namely, to bring the rays to a sharper focus than would be possible with a simple lens.

In the camera the image is focused by adjusting the distance between the lens and the photographic plate or film. Fishes focus their eyes in a similar manner, varying the distance from lens to retina. But in the human eye this distance is fixed and the shape of the lens is changed instead, being made more convex the shorter the distance from the eye to the object viewed. The shape is controlled by muscles surrounding the lens near its periphery. The changes in curvature take place almost entirely at the front surface of the lens.

While focusing for various distances is accomplished entirely by varying the curvature of the lens, it is at the front surface of the eye that most of the refraction or change in direction of the rays occurs. That is to say, the cornea (disregarding the slight effect of the thin outer layer, the conjunctiva) plays the major part in converging the incoming rays of light. This is because of the fact that the greatest change in optical density encountered by the rays is in passing from the air into the cornea. Here the index of refraction changes from 1.00 to 1.37, while in going from the aqueous humor into the lens the index changes only from 1.34 to 1.42, and in leaving the lens, from 1.42 to 1.34. (The value 1.42 is the equivalent index for all the layers of the lens taken together.) Thus the cornea, aqueous humor and crystalline lens together

form a sort of compound lens, one unit of which (the crystalline lens) is variable in shape.

In some eyes the shape of the lens cannot be changed sufficiently to focus the rays upon the retina, except when the object viewed is relatively far from the eye or near to it, as the case may be. Then we say that the person is "far-sighted" or "near-sighted." An extra convex or concave lens of glass (spectacles) may be placed in front of the eye to assist the crystalline lens by increasing or decreasing the total convergence of the rays.

But while some eyes show these and other defects, and while even a perfectly normal eye is not quite perfect in all respects as an optical instrument, the approach to perfection in the eye is, on the whole, unequaled in any optical device which man has invented for use under similar conditions. Some special "correction" devices used in the eye will illustrate nature's remarkable adaptations. Spherical aberration, common to glass lenses and very pronounced in uncorrected lenses as thick as that of the eye, is almost perfectly corrected for by varying the refractive index of the lens from layer to layer, as described above. Curvature of the surface in which the image is formed ("curvature of field") is completely compensated for by using a receiving screen (the retina) with almost exactly the same curvature as that of the image surface. Scattered light is almost completely absorbed by the pigment in the iris and by innumerable granules of pigment in a layer of cells lying under the sensitive cells of the retina. This layer of cells also serves to prevent halation, or spreading of the image by scattering in the retina.

At least several minutes are required to develop the picture taken with a camera. But the eye "develops" its picture (in the retina) and transmits it by "wire" (the optic nerve) to "intelligence headquarters" (the brain) almost instantaneously. Furthermore, the pictures are in full color and the eye restores its "photographic plate" and is ready for the next picture within a small fraction of a second. The most ingenious photographic device of man cannot duplicate these amazing feats. Nature's cameras remain inimitable.

A MARVELOUS ACOUSTICAL INSTRUMENT

The ear is an instrument for changing sound vibrations into movements which stimulate the auditory nerve, causing electrical impulses to pass along this nerve to the brain. The mechanism of the ear is marvelously constructed. In perfection as an acoustical device it surpasses the best instruments which an age of the telephone, the phonograph and the radio has been able to produce for the reproduction or transmission of sound. It is extremely sensitive, it does not lag or continue to vibrate after the sound has ceased, and it reproduces in almost perfect relative intensities the innumerable vibratory frequencies with which it has to deal.

Analyzed in detail, the action of the ear is complicated. It would be out of place to attempt a complete analysis here. But there are a few beautiful applications of elementary physical principles which can be described simply and which the beginning student of physics can understand.

The mechanism of hearing must first be described briefly. In this description some of the anatomical names are given for the benefit of those who may wish to use them.

The external ear (*pinna*) is a trumpet of irregular shape connected to a tubular passageway (*external auditory meatus*) leading to the inner mechanism. The trumpet serves to reflect sound vibrations into the tube, increasing their intensities.

About one inch inward from the external opening of the ear, the passageway is closed by a membrane (*membrana tympani*, tympanic membrane, or eardrum), upon which the sound waves fall and which is set into vibration just as the head of a drum is vibrated by sound waves falling upon it. Three small bones (the *malleus*, *incus* and *stapes*, in this order) are placed behind the eardrum. The malleus and incus are suspended in such a way as to allow them to act as levers lying approximately parallel to each other. The longer lever arm of the malleus is fastened to the eardrum, extending across it radially from near one edge to a point near the middle. The other end or head of the malleus is in contact with the head of the incus, while the opposite end of the incus presses against the third bone, the stapes, suspended at right angles to it. The end of the stapes fits into and closes a small oval window (*fenestra ovalis*, which means simply "oval window") of a system of chambers and curved tubes (*vestible* and *cochlea*) embedded in the temporal bone and filled with liquid. Only the cochlea is concerned with hearing. It is a tube wound spirally, like a snail shell, whence its name. Really it is three tubes wound side by side, since it is divided longitudinally by a spiral lamina of bone and two membranes attached to the edge of the lamina. On one of the membranes is attached a series of special sensitive cells, by means of which hearing is accomplished.

A small muscle attached to the handle of the malleus, which, as has been noted, is attached to the eardrum, keeps the drum stretched into the shape of a shallow cone. This muscle and another attached to the stapes also keep the three little bones pressed together at their points of contact, preventing knocking and slipping. As the eardrum vibrates, the two bony levers transmit the movements to the stapes, which acts as a plunger in the oval window, transmitting its vibratory movements to the liquid, which fills the chambers and tubes. These movements in the liquid of the cochlea stimulate the sensitive cells which have been mentioned and which are connected with the auditory nerve. Electrical impulses are generated and transmitted to the brain, and thus the sound is "heard."

In order to transmit faithfully the complex sound waves falling upon it, the eardrum must respond to all frequencies of vibration equally well. If it is to do this,

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You Should Read . . .

The Advancing Front of Science

● *By* GEORGE W. GRAY. Whittlesey House, McGraw-Hill Book Co., Inc., New York. 1937. xiii + 364. $3.00.

An experienced journalist who is not a scientist writes about scientific research and modern trends in science. He does a good job in presenting in a form that is easy to take authentic information about recent advances in several fields of science. A book of this kind is of great help to the teacher who would keep in touch with scientific progress in other fields than that of his major interest. The good teacher of chemistry, for example, must not only know his own subject, but he must also be informed of current developments in physics, biology, astronomy, geology, and the other sciences.

Some of America's greatest scientists have cooperated with Mr. Gray in his interesting task. Their assistance guarantees the authenticity of the material presented. To one interested in science, and even to the general reader, parts of this well-written book will be more interesting than any novel. *J. F. M.*

The Amateur Scientist

A science journal published by the American Institute of the City of New York, 60 E. 42nd St., New York City. $0.50 per year (8 issues).

Science teachers and high school pupils will be delighted with this interesting little magazine that is written and illustrated by high school students. Thirteen numbers have already been published.

In the March number readers are told how to make a reflecting telescope, how the sound effects of radio are produced, how a micro-manipulator may be constructed, and how to do other interesting things. A cross word puzzle, a book corner, cartoons, and a page of brief science facts are included. *H. C. M.*

New World of Chemistry

● *By* BERNARD JAFFE, Chairman, Department of Physical Sciences, Bushwick High School, New York City; Silver Burdett Co., New York. 1937. xxxi + 566.

This is the 1937 revision of the interesting high school text which made its first appearance in 1935 and which received a favorable review by William H. Neely of the Fifth Avenue High School, Pittsburgh, in the *Science Counselor* for December, 1935. All the statements made at that time still hold good. In addition, the subject matter has been brought up-to-date. New matter, such as the isolation of pure vitamin E, artificial radioactivity, and advances in glass technology, is included. *H.C.M.*

Science Experiences With Home Equipment

● *By* CARLETON JOHN LYNDE, Ph.D., Teachers College, Columbia University; International Textbook Company, Scranton, Pa., 1937. xiii + 226. Illustrated. $1.00.

We are enthusiastic about this book which describes 200 science experiments that can be performed at little or no expense with simple home equipment such as milk bottles, coffee cans, sink stoppers, paper bags, and other easily obtained materials.

Here are sure-fire experiments that are suitable for the classroom, the science club, the auditorium program, the guest night. Pupils, and teachers as well, will be interested in learning how to pop an egg into and out of a milk bottle; how to make a barometer from a bottle, a soda straw, and a toy ballon; how to make gliders and helicopters; how to make a hiccup bottle, a water wheel, and other scientific toys. The explanation of each experiment is clearly stated.

If you have a dollar to spend for teaching helps, buy this book. *H. C. M.*

Program Planning

Continued from Page Fourteen

The problems are followed by suitable experiments which are written out in the semester or annual plan, and will not be given in detail here. Each experiment is provided for by properly filling in each of the following heads in the plan used above.

Title of Experiment

Directions:
Object of Experiment:
Procedure:
Observation:
Conclusion:

Vocabulary

A long list of words taken from each of the problems studied, and classified and properly arranged.

Next in this plan comes a heading called

Enrichment Materials

Class room reports:
Projects to be used:
Library Reports:
References:

This plan, which is mimeographed and bound in book form, is in daily use in the science department. Its compactness and inclusiveness make it a very useful handbook for the teacher. Its use gives assurance of arriving at the goals of achievement without confusion or loss of time. The volume containing one semester's work contains only thirty pages, but it includes the fundamentals and essentials for that part of the year's work.

The plan should make provision for exhibits of science work and of science apparatus, as a means of stimulating the students taking the courses, and as a means of acquainting the public with the progress being made in these subjects. The exhibits may be set up in the school building, in a downtown place, or at some fair. They may be neat and attractive, thereby creating a desire for a study of the work. They will draw attention of the laity to that phase of education in which, perhaps, they failed to receive organized instruction. A very creditable exhibit of this type was observed recently by the writer upon a visit to St. Anthony's high school, Beaumont, Texas, in company with Dr. L. A. Woods, State Superintendent of Public Instruction. Here we saw exhibited in the auditorium of this high school a very pleasing arrangement of models of apparatus used in the various sciences, and a neat assortment of work performed by the students.

The plan of instruction should provide for a science club or clubs, and should carry an outline of the club work to be undertaken.

The proper use of program planning and the making of units of instruction in the high school sciences in Texas, though not universally used, has been sufficiently demonstrated to prove its worth. Greater interest has been stimulated in the study of the sciences through better preparation on the part of the teacher for the work to be accomplished. Thus, the teaching of this subject has been materially improved during recent years, and has been made more fruitful of satisfactory results.

Care of Shade Trees

Continued from Page Twelve

had to die from malnutrition can now be given scientifically prepared food which will supply the elements found lacking and restore them to full vigor and usefulness.

In one other interesting particular the growth processes of the tree and the human body differ. Each has a complete circulatory system, the duty of which is to carry digested food and water to different parts of the structure that growth may be made. In the human body this circulatory system is within and growth comes outside of it, while in the tree it is on the outside, just under the outer layers of bark, and the growth of the tree comes within it.

The effect of this difference is most important in connection with external injury. A mishap which makes a surface wound on the human body will be healed from within. Kept free from infection the tissues will rebuild until, many times, what seemed a serious wound leaves but slight trace. But a surface wound on a tree destroys the tiny channels which form the circulating system of the tree, and growth in that particular spot stops until the wound heals over from the sides. Enough surface wounds will so effectually stop circulation that a tree will die. We now know that one of the most important things in guarding the health of trees is to protect them from bark injury as far as possible.

The importance of the study of insect enemies of the trees is perhaps best illustrated by the case of the common aphid, of which there are a number of species. This little creature lives on the juices of the plant to which it attaches itself. In the smaller forms of plant life he and his fellows are commonly known as plant lice. The aphid has a sharp beak, which pierces the outer skin of the tree leaf or stem and draws out the sap from beneath the surface. These insects are tiny, but they multiply rapidly and they can often be found literally by the millions on a neglected tree.

Because the aphid feeds from beneath the surface of the leaf or stem, no surface poison will affect it. It plunges its beak right through the arsenic preparations which are fatal to the leaf-eater, and draws food from a source which the poison has not touched. Under the microscope, however, it has been found that the aphid has a breathing system all its own, drawing in air through a couple of tiny tubes in his body. It is evident, therefore, that a poison spray which will actually touch the body of the insect will be drawn into the lungs and cause death. These sprays, usually made with nicotine sulphate, are known as contact sprays, because they are effective only when they actually touch the insect.

The aphid, by the way, should be of great interest to the student of biology. It is a sort of freak of nature in that it is able both to lay eggs and to produce living young. The life cycle of the aphid commences with an egg which lives through the winter attached to some

tree or plant. These eggs seem to produce only female aphids, and these females and all the generations of their progeny born during the summer months are produced alive in broods of ten or twelve. Further, there is no evidence of male insects in these summer broods, or of any mating process. In the latter part of the season, however, males commence to appear, mating takes place and eggs are laid in sheltered spots to winter over and start a new life cycle in the spring.

Studies of other forms of insect life have produced similarly complete knowledge of their life cycles and habits, with the result that it has been possible to devise effective methods of control.

As a living and breathing organism, the tree has almost the same requirements for a healthy long life as a human being. It must have enough of the right kind of food. It must have water. It must have air and light. It must be protected from physical injury and from the attacks of enemies, whether insects or disease. And it will not get along a great deal better when these physical needs are neglected than would a human being under like circumstances.

How well it pays to give our trees the care and protection which will keep them healthy and strong is being realized more completely as knowledge and appreciation of intelligent tree service becomes more general. Our shade trees are the glory of our most beautiful and prosperous cities. Our ornamental trees add beauty, and our fruit trees give food and refreshment.

There is no finer manifestation of the beneficence of nature than our trees. And we owe a deep debt of gratitude to science for helping us to learn how to take care of them.

Teaching in Puerto Rico

Continued from Page Three

ploratory period in which the child will survey his environment. He will begin with himself, his person and daily habits, such as bathing, dressing, feeding, and sleeping. Next the home will be considered. Later will follow a study of the geological, meteorological and astronomical phenomena of the town and region where the child lives. During the second year he will be taught to interpret his environment and life situations, so that during successive years he will develop an understanding attitude, and the right method of thinking. Another improvement in science instruction will be obtained by increasing the scientific knowledge of the teachers and improving their attitude. Personality and mastery of subject matter and pedagogical principles are needed by a teacher who would lead his pupils into the realm of nature.

It is hoped that science teaching in Puerto Rico will develop the student's aesthetic and intellectual understanding, and above all inspire him to continue the observation and study of nature as a source of adjustment, efficiency and happiness.

Atmospheric Electricity

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lows the second with approximately the same pause between strokes. The third stroke is similar to the second, consisting of a dart leader and return, and following the same track. A single flash is, therefore, composed of double strokes which follow the trail mapped out by the stepped leader and average about 5 per flash. Schonland observed one flash with 27 strokes, the whole flash lasting about 0.5 second. He also photographed one flash consisting only of a stepped leader and return.

The first stroke differs from the succeeding strokes of a flash in two respects: it is brighter and more heavily branched. The stepped leader marks out a devious course as the streamers feel their way down. As a result, some of the streamers branch downward as they advance. These branches are also followed by successive streamers and are brought to full brilliancy by the first return stroke. The first return shows maximum luminosity at the earth, losing its brightness as it travels upwards and feeds energy into the branches, and reaching a minimum at the cloud. No flash has been photographed yet which shows maximum intensity at the cloud. The brightness diminishes as the other strokes of the flash follow, as though the first stroke had absorbed a large share of the energy, and the others were draining the remainder from the earth-cloud system. Furthermore, the strokes after the first do not show branching; they follow the main channel, but do not supply energy to the side branches.

Schonland's results have been confirmed by others using rotating cameras of different design, but none has obtained the great mass of detail clearly shown on his plates. Appleton and his colleagues have obtained somewhat different evidence in their work on the study of "atmospherics," the natural disturbances that interfere with wireless reception. They have used the cathode ray oscillograph to follow the rapid changes in the earth's electrical field, due to distant and nearby thunderstorms. The oscillograph may detect electrical characteristics of the lightning flash that do not appear on the photographic plate. Their work, which is still in progress, may supplement that of Schonland and give a clear, unambiguous explanation of the whole process of lightning phenomena.

Many details still remain to be discussed about the whole subject of the lighting discharge: the various types that have been observed such as ball, beaded,

sheet and so on; protection against lightning for buildings, power transmission lines, oil tanks, and aircraft; damage to property, animals and humans; interference with radio reception; lightning insurance; and artificial lightning. These practical matters are worthy of separate consideration by themselves and may well constitute a topic for future examination.

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Detailed data about the location and frequency of thunderstorms, magnitudes of quantities involved, and the like can be obtained from Brookes' report in *Meterological Office Geophysical Memoir* number 24, 1925.

Vegetative Propagation

Continued from Page Ten

willow (Fig. 9), the new growths arise from the cambium tissue, the only active tissue in such a stem. How often has even the most casual observer noticed the new branches emerging from the outer region of the stem just inside the bark of old tree stumps. All such growths are cambial in origin, that is, they arise from that active tissue which is situated between the xylem and the phloem and normally gives rise to new cycles or rings of these conducting structures. Under certain conditions we not only find these growths on old stumps of trees but also do we see whisker-like twigs and branches issuing from the trunks of great trees. These take origin directly from the cambium layer not very far beneath the bark. The phloem cycles are relatively few as compared with those of the xylem or woody part of the stem. This is true because much of the phloem metamorphoses into the bark of the tree, and only the younger portion of this part of the conducting system, the sieve tubes and companion cells, remain.

CONCLUSIONS AND SUGGESTIONS

These commonplace demonstrations which some of our well-known forest trees and other plants present, give us the cue to the possibilities for vegetative propagation in such cases. The horticulturalists and the orchardists are keen observers of all such manifestations in nature which enable them to predict experimental results. Fair responses have even been attained where nature offered no guarantee of such success. This shows that most plants, unlike the higher animals, have tissues which are so active, so plastic and so constituted as to initiate whole new plants from certain organs or tissues of old ones; for all of these vegetative growths might be likened to asexual reproductive and regenerative processes in animals, which processes are, however, more or less restricted to the lower and less complex animals, with a rather definite and consistent decrease of this regenerative power with the increasing complexity of the animal organism.

The few suggestions which we offer in this sketch as well as those which appeared in the *Science Counselor* for June, 1937, under the title "Seed Germination," we hope will serve to demonstrate how little in the way of equipment is necessary to adequately teach many of the most interesting and practical processes in plant life. These brief articles can give only a slight hint at what can really be done with no more apparatus than some pickle jars, a little cast-off glassware and a few flower pots. (Broken window glass may be cut into pieces to serve as covers for various cultures and improvised terraria and aquaria). These, together with a little window space and an alert teacher with a stimulated class, will provide an abundance of material for observation, not to mention the great out-of-door laboratory which is free for all. At the same time that the material is in progress of development for such demonstrations as these articles point out, there will be ample opportunity for the demonstration of such physiological processes as plant respiration, photosynthesis, absorption, response to light and darkness, temperature, moisture, etc. Material will be at hand, too, for the gross study of leaf, stem, root and other plant structures. With the set-ups in the class room there is always material for first-hand observation and demonstration. Repetition of processes and phenomena are continuous and with the interest and discussions which these stimulate, teaching really becomes effective and a pleasure.

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The drawings of the illustrative material employed in this paper were done by Miss Verna Schultz.

Duquesne University Science Conference

Some four hundred teachers attended the sixth annual conference for teachers of science in the Catholic high schools which was held at Duquesne University on Saturday, February 19. They were welcomed by the Most Reverend Hugh C. Boyle, Bishop of Pittsburgh; Reverend Paul E. Campbell, Superintendent of Parish Schools, and the Very Reverend J. J. Callahan, C.S.Sp., President of Duquesne University. Dr. Hugh C. Muldoon, Director of the Conference, presided.

Formal addresses were made by Dr. James N. Rule, principal of Langley High School, Pittsburgh, sometime state superintendent of public instruction; Sister Mary Ellen O'Hanlon, chairman of the department of biology, Rosary College, River Forest, Ill., and Howard J. Leahy, of the department of psychology, Duquesne University. These addresses will be published in future issues of THE SCIENCE COUNSELOR.

During the day announcement was made that the Conference has accepted an invitation to become affiliated with the American Science Teachers Association, which is associated with the American Association for the Advancement of Science.

A more complete account of the Conference will appear in our June issue.

Educational Field Trips

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tion to the day's adventures. At every stop the phenomena to be observed are described, questions solicited and answered, and opportunity given to collect specimens of rocks, minerals and fossils. At the last stop of the day, the observations made during the trip are usually summed up.

Trips have been run in past years in Chambersburg, Harrisburg, Johnstown, Reading, Bryn Mawr and Stroudsburg. Another, out of Pottsville, was conducted recently. On these trips an average attendance of thirty to thirty-five has been maintained. Persons who are interested and who wish further information concerning these trips are urged to communicate either with the writer or with Dr. Bradford Willard of the Pennsylvania Topographic and Geologic Survey, Harrisburg.

Biological Applications

Continued from Page Twenty-one

it must have no natural period of vibration of its own; it must not resonate to any particular frequency. Designers of radio and telephone apparatus may well envy the practically perfect attainment of this ideal condition by simple means in the eardrum. The membrane is composed of fibers running both radially and circularly. These fibers vary in length and in tension. Therefore each alone would have a natural period of vibration, determined, as in the case of the piano or violin string, by the length, mass and tension of the fiber. But taken together, the fibers form a diaphragm having no natural period, which vibrates as well for one frequency as for another. Without such impartial action, the true quality of complex tones would be lost, since certain overtones would be unduly magnified or reduced. Sounds of various pitch would be registered with incorrect relative intensities, some too loud, others too faint. But, constructed as it is, the eardrum responds perfectly to all audible sound waves falling upon it.

While in the eardrum resonance is carefully avoided, in the cochlea it is turned to good account. Here simple tones ranging in frequency from about 20 to 20,000 vibrations per second must be "placed" as to pitch, and complex tones must be analyzed. The ear does this by means of a resonating membrane (basilar membrane), one of the two membranes which, with the spiral lamina, divide the cochlea into its three spiral chambers. This membrane is made up of approximately 10,000 transverse fibers, with various lengths and tensions and supporting various masses of cells. Each fiber has a natural period of vibration corresponding to its particular length, tension and load, and so will vibrate sympathetically when that same frequency is represented in the vibrations of the fluid of the cochlea. The movements of these fibers affect the sensitive cells, each of which sends its little electrical impulse to the brain. Thus we distinguish the various pitches of the sounds which we hear. If a sound is complex, like the sound of a violin string or of the human voice, each frequency of vibration in the sound affects a different fiber or small group of fibers. In this way the "quality" of the tone is reproduced faithfully in the consciousness of the listener.

The mechanism of the ear is interesting also as a mechanical and hydraulic device for converting the pressure of the sound waves into an effective pressure many times greater. One end of the stapes acts as a plunger or piston in the oval window, as has been stated. The malleus and incus, acting together as levers with arms in the ratio of about three to two, transmit to this plunger a force approximately fifty per cent greater than the total force on the eardrum. But the cross-sectional area of the piston is only about one-twentieth the area of the drum. Therefore, the pressure on the fluid of the cochlea is about thirty times as great (20x1.5) as the pressure on the drum.

The sensitivity of the human ear is astounding. Only in very small part can it be accounted for by the increase in pressure effected by the drum and its levers and piston. It has been found that a sound with a frequency of 2,000 vibrations per second may be audible to a sensitive ear when the energy falling on the drum each second (roughly $5x10^{-11}$ joules or $1.2x10^{-11}$ calories) is so unbelievably small that if the sound continued for three thousand years, the total energy would be only a little more than enough to heat a gram of water a thousandth of a degree Centigrade!

The minimum amplitude of movement of the drum detectable by the listener is no less remarkable. It has been found that movements of approximately a hundred-millionth of a millimeter can be detected. It is difficult to understand how such minute movements of the drum, only about one-twenty-fifth the diameter of a hydrogen molecule, could generate impulses capable of affecting the consciousness.

(To Be Continued)

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